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Sea cucumber diversity and resources in Brunei, Borneo Island

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ABSTRACT: A wide diversity of holothurians occurs on the coastal reefs of Brunei, with 14 bêche-de-mer species being recorded in significant numbers and densities. Asexual fission apparently contributes to high population densities of *Holothuria atra* and *Holothuria edulis*. In the genus *Bohadschia*, four species are recognized and two of them are considered to be new to science. There is some evidence of illegal harvesting but surveys indicate that sea cucumber resources on Brunei reefs are, unlike those on most tropical Indo-Pacific reefs, relatively non-depleted. Given the limited domain of reef sites in Brunei territorial waters, stocks of commercial species are probably not sufficient to support a viable national fishery, but the resource of high-value commercial species is of importance, not only in terms of biodiversity, but as viable natural breeding populations as well as a source of broodstock for mariculture research.

1 INTRODUCTION

Fisheries for tropical Indo-Pacific sea cucumbers are typically unregulated and many stocks are overexploited (Conand & Byrne 1993, Conand 1998). Concerns range from loss of biodiversity and fishery productivity, to the possible deleterious ecological effects of sea cucumber biomass-depletion on reefs and associated marine sediments. In some localities many highly prized (and priced) species have become very rare – so much so that they have been suggested as possible candidates for CITES listing (Conand 2002, Bruckner et al. 2003).

In contrast to most Indo-Pacific reef habitats, shallow shelf waters off the Brunei sector of the N.W. Borneo coastline are, in terms of sea cucumbers, unexplored and unexploited, at least in recent years. There are no licences issued for bêche-de-mer harvesting and, as a consequence, no national fishery data exist for this resource in Brunei. The limited area of reef habitat in Brunei is one reason for lack of commercial interest in reef-associated sea cucumbers but holothurian resources remain relatively undisturbed partly as a consequence of offshore oil and gas facilities and their exclusion zones placing many large reef areas and shallow sediments off limits for fishing.

Coral reef areas in Brunei waters, estimated to be approximately 4500 ha in total extent (Chua et al. 1987), have been little documented in terms of their biota, except for corals and fish (Chua et al. 1987, Rajasuriaya et al. 1992). Most of the reefs are bank reefs (Fig. 1) at depths ranging from 6–20 m. These reefs are thus not accessible to gleaners and, in general, fishing activities are of low intensity and tend to be non-destructive. Preliminary SCUBA observations in 1991 (Rajasuriaya et al. 1992) and 2003 (this study) indicate the existence of a rich and mature coral fauna, a high live-coral cover – particularly offshore – and significant sea cucumber populations, all indicators of relatively undisturbed habitats. Surveys initiated to document the diversity of sea cucumbers are reported here, focusing in particular on commercially desirable species, and their population abundances and size structure.

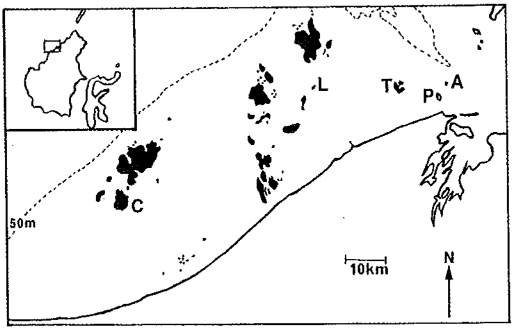

Figure 1. Map of Brunei coastline and its near-shore reefs. A = Abana Reef, C = Chearnley Shoal, L = Littledale Shoal, P = Pelong Rocks, T = Two Fthm. Rocks.

Table 1. Distribution of commercial sea cucumbers on Brunei reefs.

	Pelong Rocks	Two Fthm. Rocks	Abana Reef	Littledale Shoal	Chearnley Shoal
Thelenota ananas		*	*	*	
Thelenota anax					*
Stichopus chloronotus		*			
Holothuria fuscogilva			*		
Holothuria whitmaei		*			
Holothuria edulis	*	*		*	
Holothuria atra	*				
Bohadschia argus	*	*	*	*	
Bohadschia vitiensis		*		*	
Bohadschia sp. 1		*			
Bohadschia sp. 2		*			
Pearsonothuria graeffei	*	*	*	*	*
Actinopyga lecanora		*	*		
Actinopyga miliaris			*		*
Actinopyga palauensis	*	*			

2 MATERIALS AND METHODS

Where sea cucumber abundances are low, SCUBA survey methods consisted of relative abundance counts within a belt 5 m either side of swim-lines, each conducted for 45 minutes to 1 hour. Reefs with abundant sea cucumbers were censused using tape measure transects either 30 or 60 m long and with a belt width of 4 m. Thorough searches of adjoining regions provided additional samples and data for population analyses. Collected sea cucumbers were weighed (including ingested water and particulates) using a Salter spring balance (during calm conditions) and then returned to the reef. Data were analysed using the non-parametric Mann-Whitney *U test* (Sokal & Rohlf 1981). Selected specimens were photographed and some, particularly *Bohadschia* species of questionable identity, were collected as voucher specimens and for ossicle studies.

3 RESULTS

3.1 *Diversity and distribution*

Within the aspidochirote families Holothuriidae and Stichopodidae, 14 bêche-de-mer species have been identified in Brunei waters. The distribution of these is shown in Table 1, although the survey coverage is not yet completed. Several of the more distant reefs have yet to be adequately sampled or have been surveyed only qualitatively, due to the difficulty of working offshore in small boats without the benefit of islands for protection. These 14 large, non-cryptic species are accompanied by another, *Pearsonothuria graeffei*, an abundant, conspicuous species of little commercial value.

Table 2. Holothuria atra densities at Pelong Rocks (south east side).

Transect no.	Transect area m^2	Count	Density/m^2	Extrapolated density/ha
1	120	3	0.025	250
2	120	4	0.033	330
3	120	67	0.558	5580
4	120	77	0.642	6420
5	120	54	0.450	4500
6	120	48	0.400	4000

3.2 *Population parameters*

Two sites, namely Pelong Rocks and Two Fthm. Rocks, were surveyed in more detail during this first phase of an ongoing survey. The highest sea cucumber densities were found on fringing reef platforms on the S.E. side of Pelong Rocks, a small cluster of rocky islets near Brunei Bay. At this site *Holothuria atra* predominates and attains densities as high as $0.642/m^2$ – equivalent to 6420/ha (Table 2). This compares with a peak density of $6.6/m^2$ reported for this species at Reunion Island (Conand & Mangion 2002). *H. edulis* was uncommon on the Pelong S.E. platforms but abundant (not quantified) on the N.E. side of Pelong. The high abundances of *H. atra* and *H. edulis* at Pelong probably reflect the fact that: (a) this island locality has enjoyed protection since 1967 and is now nominated as a Marine Sanctuary and (b) both these species are capable of reproducing asexually by fission – thereby boosting in situ populations.

Analysis of population size structure for *H. edulis* at Pelong Rocks (Fig. 2a) indicates a unimodal distribution with a bias towards the smaller sizes (0–150 g). This skewed pattern is indicative of

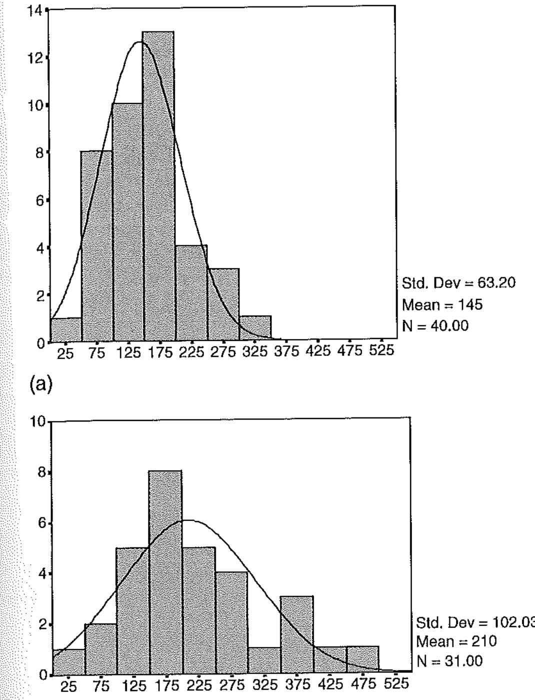

Figure 2. Size frequency distributions for *Holothuria edulis* at (a) Pelong Rocks and (b) Two Fthm. Rocks (weights in grams – x axis; frequency – y axis).

recruitment to the stock, either by sexually derived progeny, or by asexual fission. The sample size for *H. edulis* at Two Fthm. Rocks (Fig. 2b) is not large but the distribution appears normal, with the curve displaced by a small secondary peak in the larger size categories. *H. edulis* surveyed at Two Fthm. Rocks had a statistically higher mean size (210 g) than at Pelong (145 g) (Mann-Whitney *U* test, $P < 0.0025$).

The pattern in the size frequency data for *Holothuria atra* is also unimodal and essentially normal (Fig. 3); over-representation of the smaller size classes suggests recruitment to the stock. Asexual fission almost certainly plays a part in the reproductive biology of both these Holothuria species as some of the smaller sizes show visible evidence of recent tranverse fission or regeneration. The lack of juvenile size classes is consistent with non-seasonal recruitment of fission products to the stock, as suggested for *H. atra* populations at Rongelap Atoll (Bonham & Held 1963).

At Two Fthm. Rocks the most abundant sea cucumber was *Stichopus chloronotus* with a peak density equivalent to 416/ha recorded (Table 3). *S. chloronotus* has thus far been sighted only at Two Fthm. Rocks, where its population also shows a unimodal size

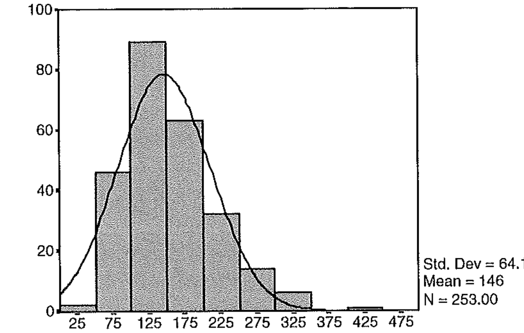

Figure 3. Size frequency distribution for Holothuria atra at Pelong Rocks (weights in grams – x axis; frequency – y axis).

distribution (Fig. 4a). Other sea cucumber species at this site scored maximum extrapolated densities of 125/ha (*Bohadschia argus* & *Pearsonothuria graeffei*) and 41/ha (*Actinopyga lecanora*) (Table 3). *P. graeffei* size distribution at Two Fthm. Rocks, based on a limited sample size, is also essentially unimodal (Fig. 4b).

The large, high-value bêche-de-mer species, *Thelenota ananas* was found at Two Fthm. Rocks (but not in any of the belt transects) and at all other reefs except Pelong Rocks (close to Brunei Bay) and Chearnley Shoal (which has yet to be comprehensively surveyed). At Two Fthm. Rocks T. ananas ranged in size from 1500–2950 g. Specimens seen at other sites were likewise large and mature. From 1 to 4 individuals were commonly seen on dives and the limited transect data for Littledale Shoal indicate densities as high as 1 per 240 m^2 (approx 41/ha). A single individual of *T. ananas'* larger relative, *Thelenota anax*, has been recorded in the Chearnley Shoal region and divers report that it is not uncommon in that area.

Other high-value target species, such as *Holothuria fuscogilva*, *Holothuria whitmaei* (referred to as *H. nobilis* by some authors), *Actinopyga lecanora* and *Actinopyga miliaris*, were recorded only in small numbers or as single individuals. *A. lecanora* is, however, semi-cryptic and it is possible that the density value of 41.7/ha, determined for Two Fthm. Rocks, may be an underestimate. Several bêche-de-mer taxa in the genus *Bohadschia* were recorded, with *B. argus* being the most widespread and abundant – attaining extrapolated densities of 125/ha at Two Fthm. Rocks. Three other *Bohadschia* species, whose uncertain identity is addressed below, occur in small numbers or are burrowing forms and hence not readily counted during daytime surveys.

3.3 *Taxonomy*

Four *Bohadschia* species or varieties were found but since the identities of three of them were uncertain,

Table 3. Sea cucumber densities at Two Fthm. Rocks.

	Transect no.	Transect area m²	Count	Density (/m²)	Extrapolated density (/ha)
Stichopus chloronotus	1	120	2	0.008	83.3
	2	120	10	0.042	416.7
Bohadschia argus	1	120	3	0.013	125
	2	120	1	0.004	41.7
Pearsonothuria graeffei	1	120	3	0.013	125
	2	120	1	0.004	41.7
Actinopyga lecanora	1	120	1	0.004	41.7
	2	120	0	0	0
Holothuria edulis	1	120	4	0.017	166.7
	2	120	2	0.008	83.3

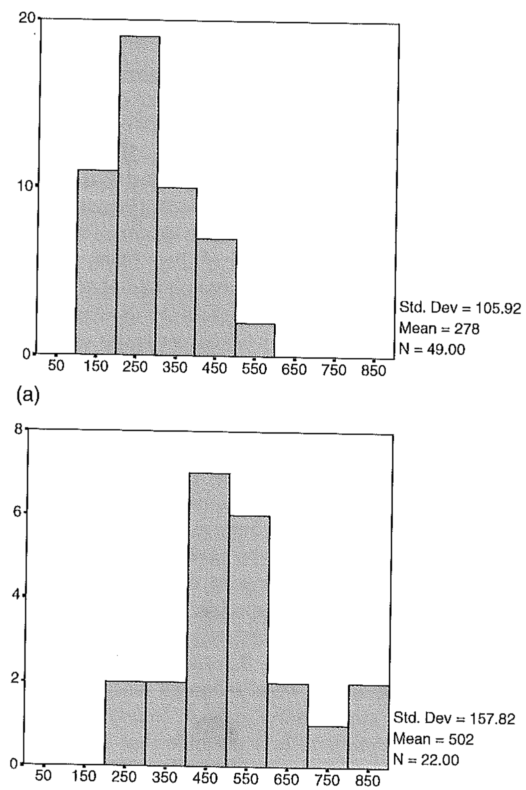

Figure 4. Size frequency distributions for (a) *Stichopus chloronotus* and (b) *Pearsonothuria graeffei* at Two Fthm. Rocks (weights in grams – x axis; frequency – y axis).

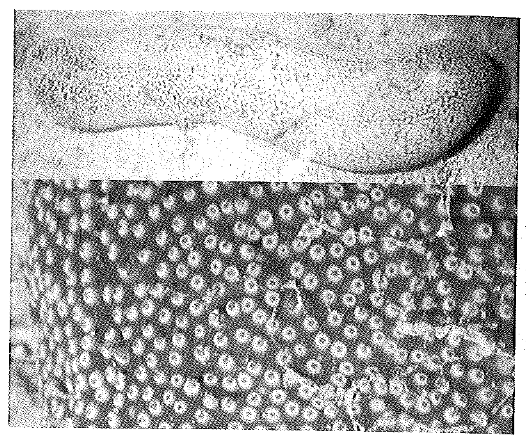

Figure 5. *Bohadschia vitiensis* at Two Fthm. Rocks (above) and close-up of body wall of another specimen (below).

ossicle preparations were made. One of them (Fig. 5) is a large, uniformly brown form with densely-crowded, pale-ringed, small, darkish papillae distributed without any pattern on the upper surface, except for a pair of characteristic ill-defined dorso-lateral, longitudinal brown lines where papillae tend to be absent.

The body appearance (Fig. 5) and ossicles of this form (Fig. 6) match the description for *Bohadschia vitiensis* (Semper, 1868) given by Massin (1999), who does not illustrate the animal in life. Ossicle similarities include the large, robust, spinose tentacle rods, sometimes branching, fenestrated and with recurved ends, and the absence of grains in the dorsal body wall. Rowe & Doty (1977) and Rowe & Gates (1995) have considered *B. vitiensis* to be a synonym of *B. marmorata* but Massin (1999) maintains *B. vitiensis* as a distinct species, a view concurred with here. A similar form, illustrated in Forbes et al. (1999) and in image no. 1027 of Gosliner et al. (1996), is assigned to *Bohadschia paradoxa* (Selenka 1867) but Rowe & Gates (1995) consider the occurrence of this species beyond the Hawaiian islands as doubtful.

Another *Bohadschia* form, *Bohadschia*. sp. 1 (Fig. 7), has a brown background colour and dense, pale-ringed papillae similar to *B. vitiensis* but is overlain with brown circular and irregular blotches bordered with pale pigmentation. In addition, its tentacle rods (Fig. 9a) are much smaller and less robust or spinose

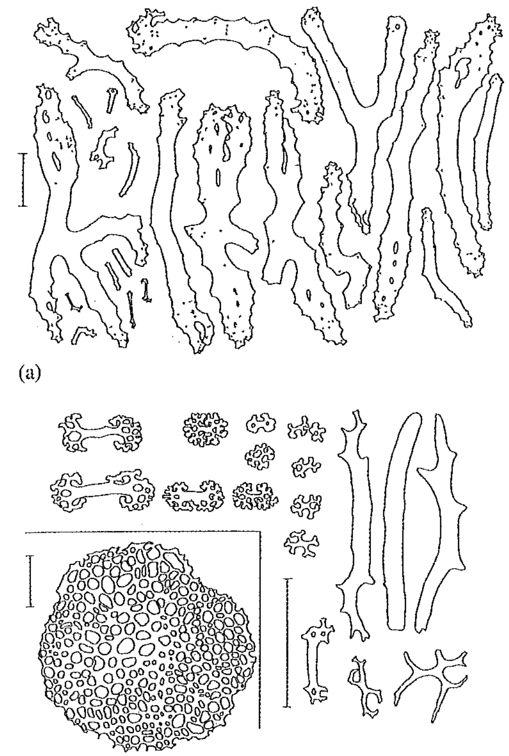

Figure 6. Ossicles from (a) tentacles and (b) dorsal body wall – including papilla end-plate, lower left – of *Bohadschia vitiensis* (upper specimen in Fig. 5). Scale bars = 80 μm.

than those of *B. vitiensis*. This form is sometimes considered to be a variety of *B. argus* (Figs. 8, 9b) but the body pigmentation and ossicles are quite different. This form may be a new species but similarity of its background pigmentation to that of *B. vitiensis* suggests a possible hybrid. A more detailed examination of its morphology and microstructure is in progress.

A second problematic taxon, *Bohadschia* sp. 2 (Fig. 10), is similar in general appearance and types of ossicles (Fig. 11) to *Bohadshia subrubra*, as redescribed by Massin et al. (1999), but it may also be a new *Bohadschia* species. The pigmentation patterns illustrated for *B. subrubra* by Massin et al. (1999) are in fact quite varied and the Brunei specimen resembles only those in Pl. 1D of Massin et al. (1999). Ossicle similarities include the form of the tentacle rods, the predominance of granules ventrally and the lack of granules dorsally. However, a complicating factor for *B. subrubra* (and for *Bohadschia* species generally) is that the range of body-wall granules and rosettes is reported to vary according to body size (Massin et al., 1999). If *Bohadschia* sp. 2 is indeed *Bohadschia subrubra* then its occurrence off N.W. Borneo would

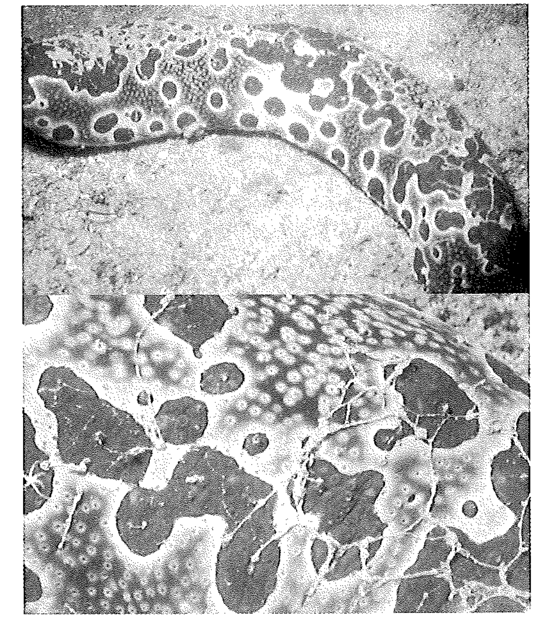

Figure 7. *Bohadschia* sp. 1 in situ at Two Fthm. Rocks (above) and portion of body wall seen in close-up (below).

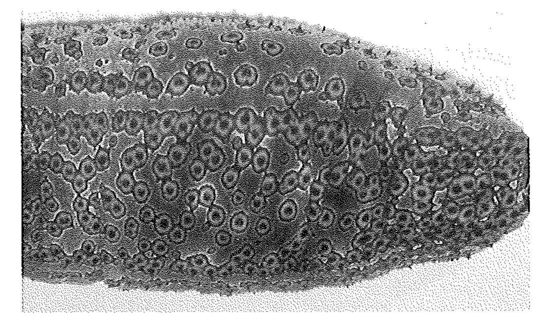

Figure 8. *Bohadschia argus* from Pelong Rocks.

represent a discontinuous extension of its known range from the Western Indian Ocean.

4 DISCUSSION

There is a considerable body of information on bêche-de-mer harvested in the tropical Indo-Pacific (much of it reported in issues of the *Beche-de-Mer Information Bulletin*, beginning in 1990), but surprisingly little data on population densities, either for exploited or unexploited stocks. Such data as exist (e.g. Lokani et al. 1996, Long & Skewes 1997, Uthicke & Benzie 2001, Conand & Mangion 2002) suggest that virgin

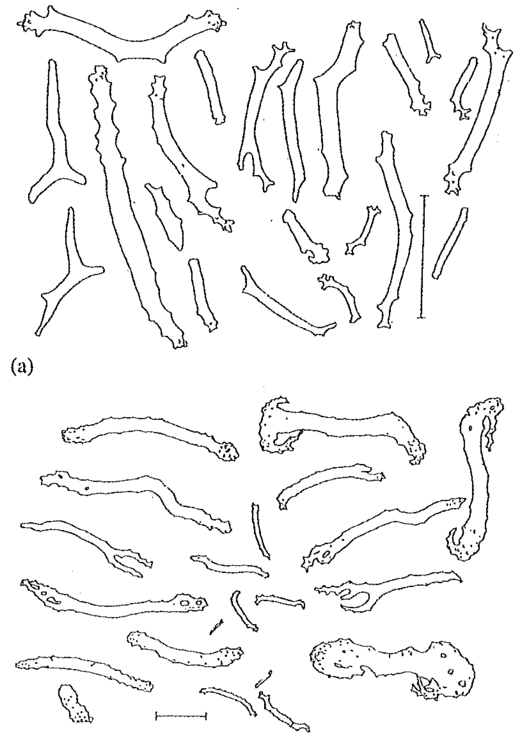

Figure 9. Tentacle rods from (a) *Bohadschia* sp. 1 in Fig. 7 and (b) *Bohadschia argus* in Fig. 8. Scale bars = 80 μm.

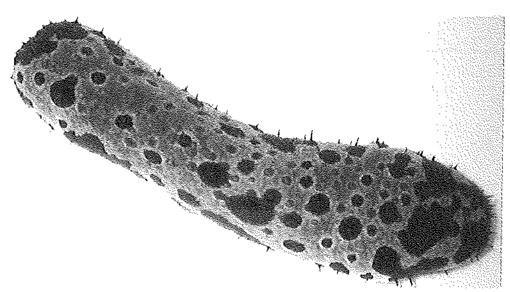

Figure 10. *Bohadschia* sp. 2.

population densities, although highly variable at different Indo-Pacific sites and for different species, are comparable to the range of densities recorded in these initial surveys for large and small species in Brunei waters [i.e. at Pelong Rocks (Table 2), Two Fthm. Rocks (Table 3) and for *Thelenota ananas* (41/ha) at Littledale Shoal]. A reduction in mean body size tends to accompany density decline in fished stocks (Uthicke & Benzie 2001) and in this regard the large body sizes observed for high value *T. ananas* (and

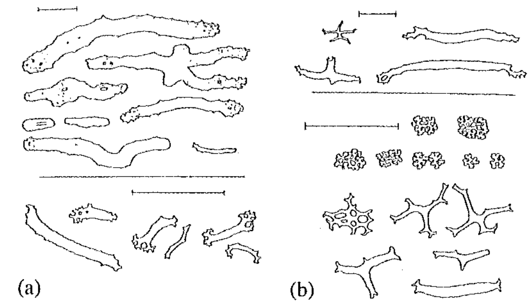

Figure 11. Ossicles from (a) tentacles and (b) dorsal body wall of *Bohadschia* sp. 2 specimen in Fig. 10. Scale bars = 80 μm.

other species) suggest relatively unexploited populations in Brunei waters.

With regard to taxonomic issues, particularly in *Bohadschia*, it is clear that certain species of this genus present problems of identification, not least because of size/age-related changes in ossicle microstructure. Consequently, validation of *Bohadschia* sp. 1 & sp. 2 as new taxa requires a detailed analysis of their anatomy, pigmentation patterns, ossicles and DNA sequences. The genus *Bohadschia* has long been in need of revision and recently *B. vitiensis* (Semper) has been resurrected from the *Bohadschia marmorata* complex (Massin 1999). Initial phylogenetic analysis of *B. bivittata* (Mitsukuri) indicates that it too is separable from the *B. marmorata* complex (Ron Clouse pers. com.).

One character, that of body pigmentation pattern, has tended to be neglected in many historical descriptions of sea cucumbers, due in part to preservation problems and image production/reproduction costs, and in part to concern over possible overlap of pattern variation within closely related taxa. High quality colour photographs of living animals, especially if taken in situ, and once taxonomic issues are resolved, will ultimately be of enormous value in enabling rapid in situ identifications and diversity assessments. Clarification of stock identity for commercially exploited sea cucumber resources is also critical in terms of management/conservation concerns.

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